Observations Regarding the Diet of Florida Mice, *Podomys floridanus* (Rodentia: Muridae)

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ABSTRACT—The diet and feeding behavior of the Florida mouse (*Podomys floridanus*) were examined during an ecological study in Putnam County, Florida. Field and laboratory observations provided additional evidence that *Podomys* takes a wide variety of plant and animal foods. Preliminary preference tests with acorns from six species of oaks suggest that acorns of the dominant species (*Quercus laevis*) in the study area are less favored than those of other species. The crash of a population where supplemental food was provided suggests that local populations are not food limited.

Almost nothing is known about the natural diet of the Florida mouse, *Podomys floridanus* (Chapman). Merriam (1890:53) reported an observation that these mice ate seeds of "scrub-palmettoes" in southeast Florida. The association of *Podomys* with turkey oaks (*Quercus laevis*) and other oaks was noted by Merriam (1890) and Bangs (1898); Layne (1970), Humphrey et al. (1985), and Packer and Layne (1991) suggested that acorns were a major food during masting years. Milstrey (1987) described *Podomys* eating engorged soft ticks (*Ornithodoros turicata americanus*) that parasitize gopher frogs (*Rana capito*) and gopher tortoises (*Gopherus polyphemus*). Presumably other foods include insects, seeds, nuts, fungi, and other plant material (Layne 1978, Jones and Layne In Press). The study by Packer and Layne (1991) is the first to examine foraging behavior of this species.

Effects of food supplies on local distributions of *Podomys* also have been poorly studied. The only attempt to determine whether populations are limited by food availability was the supplementation experiment performed by Young (Young 1983, Young and Stout 1986) on two grids in sand pine (*Pinus clausa*) scrub in Orange County, Florida. Other rodents responded to the additional food, but *Podomys* rarely appeared on grids and failed to establish a permanent population during the experiment, although the species was abundant previously. Young (1983) concluded that *Podomys* populations were limited by factors other than food.

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The purpose of this article is to report observations of feeding behavior of wild and captive *Podomys*. Additionally, I performed acorn preference tests and a supplemental feeding experiment to determine whether local distributions were due to food supply.

MATERIALS AND METHODS

Field Studies—Florida mice were trapped on the Anderson-Cue and Smith Lake sandhills on the Katharine Ordway Preserve-Swisher Memorial Sanctuary in Putnam County, Florida. These xeric sandhills are "high pine" communities dominated by longleaf pine (*Pinus palustris*) and turkey oak (*Q. laevis*). Brand (1987), Eisenberg (1988), Franz (1986, 1990), and Jones (1990) described the fauna of these sandhills. Populations of *Podomys* occur on sandhills and old pastures on the Ordway Preserve, where they are closely associated with burrows of gopher tortoises. Cotton mice (*Peromyscus gossypinus*) and golden mice (*Ochrotomys nuttalli*) inhabit lower, more mesic habitats on the preserve.

Each tortoise burrow on the Anderson-Cue and Smith Lake sandhills was flagged and marked with a unique number. Florida mice were caught in Sherman traps placed at the mouths of tortoise burrows on both sandhills. Animals were released near the burrow entrance so that I could observe escape responses and foraging behavior (Jones 1990). I used standard mark-and-recapture techniques, in which individuals were toe-clipped, sexed, and weighed. I calculated minimum trappability [(number of captures - 2)/(possible captures - 2)] for animals captured three or more times (Hilborn et al. 1976).

I used a breeding colony derived from animals captured at Ashley Old Pasture and near Smith Lake to perform food preference tests. Captive animals were housed in aquaria fitted with hardware-cloth tops. The maintenance diet consisted of rodent chow (Wayne Rodent Blox) and water provided ad libitum, supplemented with lettuce, carrots, apples, strawberries, sunflower seeds, mixed bird seed, oatmeal, mealworms, and crickets.

Preference Tests—I performed preference tests to determine whether acorns of turkey oaks (*Q. laevis*) were selected over acorns of other species present on the Ordway Preserve. At least 24 hours before beginning a test, a mouse was placed in an aquarium with clean kitty litter, nesting material, water, and rat chow. To start a trial I removed the chow and added three bowls, each containing five acorns of a single species, at about 1900 hours. Each acorn was marked, weighed, and measured, but no effort was made to ensure that all acorns in a bowl were identical in size. I controlled for location effects by shifting relative positions of the three types of acorns in each trail. Acorns with weevil holes were not used, and in a single trial all acorns either had caps or lacked them. Approximately 12 hours later I removed bowls, acorns, and acorn fragments. I recorded whether acorns were removed from bowls and whether they were opened and eaten, opened and evidently not eaten, gnawed, or apparently untouched. After discovering that some acorns lacking external holes were spoiled by insects or mold, I simplified analysis of results by recording only whether acorns were opened, regardless of whether any meat appeared to have been removed. Ranked data were subjected to the Friedman test (Conover 1980) to test the null hypothesis that species of acorns were opened in equal numbers.

Food Supplementation—The food supplementation experiment consisted of trapping at three grids, two on Anderson-Cue (designated ACI and ACII) and one on Smith Lake (SL). Each grid consisted of 10 columns and 10 rows 10-m apart, with a single Sherman trap at each intersection (area = 10,000 m^2). Prior trapping at burrows in each area indicated that mice were present, and grids were set more than 100-m apart to reduce movements of animals between grids. In April, May, and June, 1987, I trapped SL for 800 trapnights and determined that after three consecutive nights of trapping, no additional individuals were captured. Consequently, SL, ACI, and ACII were trapped for three consecutive nights per month for a total of 300 trapnights/grid monthly. On ACI I provided a mixture of sunflower seeds, mixed bird seed, and oatmeal for 1 year in seven chick feeders fitted with glass jars. To eliminate non-target species, plastic buckets with two holes (2.5 cm) cut near the rims were upended over the feeders and anchored with cinder blocks.

RESULTS

General Observations on Diet—Five feeding events were observed at Smith Lake. An adult male caught and released on SL (5 May 1988) readily ate a cricket (*Orthoptera: Gryllinae*) offered to him. On 15 June 1987 at approximately 0245 EST, an adult female (who had been trapped and released) immediately caught a small moth and consumed all but the wings. On 9 May, an adult female just released from a trap ate a young shoot of wild bamboo (*Smilax auriculata*). In July 1988, a female released from a trap at a burrow hid in a hole at the base of a turkey oak approximately 5 m northwest of the burrow. In a few minutes she left the hole, picked up a small pawpaw (*Asimina incarna*), carried it back to the hole, and ate it. Jones (1989) previously described consumption of a pawpaw fruit (*A. incarna*) by a Florida mouse at Smith Lake. Predation and dispersal of *Asimina* fruits have not been well studied, although these fruits are eaten by opossums (*Didelphis virginiana*), humans, and other mammals (Bartram 1791, Willson and Schemske 1980, Norman and Clayton 1986). Although nutritional values and fruit set have not been reported for *A. incarna*, it is the most abundant pawpaw and the largest fruit produced in sandhills on Ordway and probably represents a significant addition to the summer diet of *Podomys*.

I offered captive animals the following fruits and seeds collected at Ordway, all of which were eaten: acorns (*Q. chapmanii*, *Q. geminata*, *Q. hemisphaerica*, *Q. laevis*, *Q. myrtifolia*, and *Q. nigra*), pine seeds (*P. elliottii* and *P. palustris*), blueberries (*Vaccinium myrsinites*), deerberries (*V. stamineum*), gall berries (*Ilex galabra*), blackberries (*Rubus argutus*), gopher apples (*Licania michauxii*), pawpaw fruits (*A. incarna* and *A. pygmaea*), flowers of queen's delight (*Stillingia sylvatica*), and seed pods of legumes (*Crotalaria rotundifolia* and *Galactia elliotti*). Captive mice also shredded seeds and stems of unidentified grasses and incorporated them into the cotton nesting material in their cages; the grasses probably were eaten as well.

The ready acceptance of a wide variety of foods in my study implies that, like *Peromyscus*, *P. floridanus* is an opportunistic feeder. In general, the feeding behavior I observed in captive *P. floridanus* resembled that described for *Peromyscus* (Eisenberg 1968), in which the animal picks up food with the paws or mouth, then crouches and manipulates the food with the paws. Large items such as pawpaws were propped against the substrate. Seed pods were opened by grasping the pod vertically, resting one end on the substrate, chewing off one end, and opening the pod longitudinally along a suture. Larger foods, such as turkey oak acorns, were dragged with the incisors; smaller items were carried in the mouth. Some captives consistently cached acorns and sunflower seeds under kitty litter in corners of the aquaria. Food items and remains also commonly were found underneath nests.

Except for smaller acorns that might be split in half, acorns were opened consistently at the hilum (basal scar). Although acorns typically were carried by the point at the distal end, mice never chewed open the hull there. For small, round acorns a neat incision was made around the hilum; on more elongate nuts (*Q. geminata* and *Q. laevis*) the hull was nibbled farther down the sides. Caps, if present, were removed; there was no significant difference in the numbers of capped and capless *Q. laevis* acorns opened.

Predation on vertebrates is probably rare. On Smith Lake in 1983, J. F. Eisenberg (University of Florida, personal observation) trapped an adult male who detached and ate the posterior part (about

3.5 cm) of a juvenile red snake (*Elaphe guttata*) that was caught half way in the trap. An adult male caught on Anderson-Cue in October 1987 ate the viscera of a juvenile Florida mouse also caught in the trap. A litter of three young was eaten on one occasion when a male and two lactating females were in one aquarium.

Acorn Preferences—Unpredictable acorn supplies made it impossible to run tests with identical acorns in 1988 and 1989. Additionally, the majority of acorns on the ground already contained weevil larvae or were otherwise spoiled. In 1988, I concentrated on determining which acorns were eaten by *Podomys*. I presented acorns from six species of oaks—Chapman's (*Q. chapmanii*), live (*Q. geminata*), turkey (*Q. laevis*), laurel (*Q. hemisphaerica*), myrtle (*Q. myrtifolia*), and water oaks (*Q. nigra*)—to four captive animals. Five of these species belong to the red oak group, which generally contains three or four times more tannin (Briggs and Smith 1989) than species of the white oak group (which includes *Q. chapmanii*). Each mouse was presented with turkey oak acorns in combination with acorns from two other species; two–four trials were run per animal for a total of 12 trials. Although the sample was inadequate for statistical analysis, I noted that mice opened acorns of all species, and in all but one trial turkey oak acorns were opened in the smallest numbers.

In 1989 Chapman's and live oak acorns were not available, so I gathered acorns from *Q. laevis* and two different trees of *Q. hemisphaerica*, one from an old pasture near Ross Lake and the second from a hammock past Anderson-Cue. I expected that acorns of *Q. laevis*, the predominant oak on Smith Lake, would be preferred. I tested nine animals, two trials each. I analyzed the results of the first trial only, because there was no difference in ranks of first and second trials. Results indicated that acorns were not opened in equal numbers (Friedman test, $T = 26.75$, $P = 0.01$). For multiple comparisons at a significance level of $P = 0.01$ (Conover 1980), acorns from Ross Lake (*Q. hemisphaerica*) were opened significantly more often; differences between acorns from the hammock and from *Q. laevis* were not significant. These results indicate not only a preference for laurel oak acorns, but an ability to distinguish acorns from two individuals of *Q. hemisphaerica*.

Mice did not eat blackened nutmeats, but I did not test preferences of sound acorns versus acorns with larvae. On one occasion an adult female immediately ate a larva from an acorn opened but not eaten by another female. Semel and Andersen (1988) suggested that such differences in behavior might be due to mice being unable to detect larvae in unopened acorns, or that larvae are detected but avoided by some individuals. They also suggested that tooth marks on hulls and movement of acorns might represent assessment. Of the 450 acorns presented in 30 trials to 13 *Podomys*, 66% were removed from bowls, whether opened or not.

Food Supplementation Experiment—Individual trappability of Florida mice captured on the Ordway Preserve ranged from 14 to 100% (Jones 1990). The average trappability for 5 years of trapping was 57%. According to Hilborn et al. (1976), estimates of minimum numbers of individuals by direct enumeration become more reliable as trappability exceeds 50%.

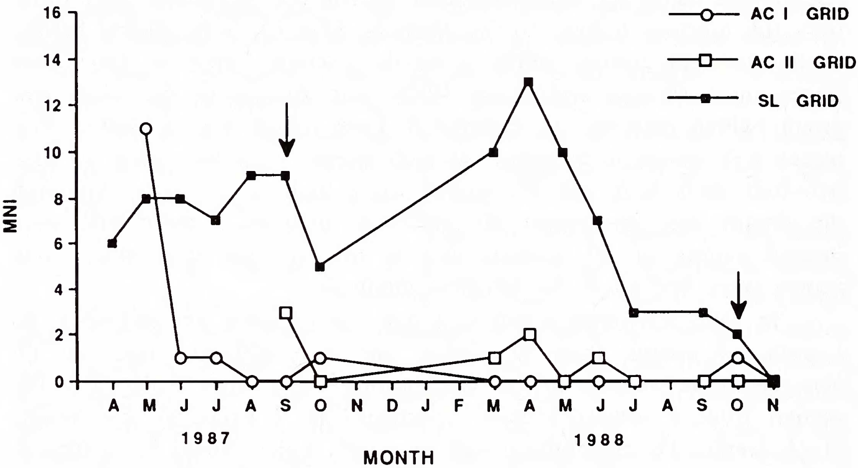

Fig. 1. Minimum number of individuals known alive (MNI) on the Anderson-Cue I, Anderson-Cue II, and Smith Lake grids in Putnam County, Florida. Arrows indicate beginning and ending of food supplementation on Anderson-Cue I.

Results of the food supplementation (Fig. 1) were similar to those reported by Young (1983) in that *Podomys* disappeared during the summer in spite of the additional food. Capture rates declined sharply on ACI where extra food was provided, although mice persisted in small numbers at burrows west and east of the grid. Maximum trapping success for a single night was 9%, and was usually much lower. Persistence (time between first and last captures) of mice on the three grids was estimated (Table 1). It seems unlikely that the decline on ACI was due to competition with immigrating rodents; the only other rodents captured on these grids were flying squirrels (*Glaucomys volans*).

Table 1. Persistence data for *Podomys* on trap grids in Putnam County, 1987-88. Data presented are minimum number known alive, mean + SD days present on grid, and total number of trapnights.

		Number of Days Present			
Grid Location	Minimum Number	$\bar{x}$	SD	Maximum	Trapnights
Anderson-Cue I	12	16	21	75	4,200
Anderson-Cue II	6	7	13	33	3,000
Smith Lake	24	123	156	517	4,100

DISCUSSION

Hulls of *Q. laevis* found in excavated burrows (Jones and Franz 1990) and vacuumed remains of *Q. geminata* and *Q. laevis* from burrows on Roberts Ranch, Putnam County (E. G. Milstrey, University of Florida, personal observation) were opened in a manner consistent with that observed with captive *Podomys*. Small piles of similarly-opened hulls occasionally were found at the base of turkey oaks and near burrow entrances on Ordway.

Acorn selection might be based on chemical composition other than tannin content. Acorns of *Q. hemisphaerica* contain more tannic acid than *Q. laevis* and more fat and carbohydrates than *Q. chapmanii* and *Q. incana* (Halls 1977, Harris and Skoog 1980). In their study of acorn preference in *Peromyscus*, Briggs and Smith (1989) found that five *P. leucopus* captured in habitats lacking oaks consumed equal amounts of acorns from species of the red and white oak groups, whereas mice from areas containing oaks selected acorns of *Quercus* species found in their habitat, independent of fat, protein, and tannin content.

Based on these preliminary results, I suggest that acorns of oaks other than *Q. laevis* are preferred if available. Turkey oaks provide an unreliable food supply. Umber (1975) noted low, variable acorn production by *Q. laevis* in Citrus and Hernando counties, and Kantola and Humphrey (1990) found that production by trees at Ordway varied with slope and tree diameter. Layne (1990) correlated the relatively greater abundance of *Podomys* in scrub and scrubby flatwoods with higher and more consistent acorn production than in sandhills. He also presented evidence that differences in morphology and behavior in scrub and sandhill populations reflect differences in vegetation structure and mast production in these habitats. Proximity to *Q. geminata* and other oak species might partially explain the relatively higher and more stable population of *Podomys* at Smith Lake, although there is no evidence that populations are food limited.

If oak species in hammocks are more reliable producers, the distribution of *P. gossypinus* and *Ochrotomys nuttalli* in hammocks at Ordway might be partly due to the acorn supply. Competition could be one factor restricting *Podomys* to sandhills when other rodents are present in contiguous habitats. However, in sandhills and other habitats elsewhere in Florida, *P. floridanus P. gossypinus*, and *O. nuttalli* are sympatric (Packer and Layne 1991, Frank and Layne 1992).

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LITERATURE CITED

Bangs, O. 1898. The land mammals of peninsular Florida and the coast region of Georgia. Proceedings of the Boston Society of Natural History 28:157–235.

Bartram, W. 1791. The travels of William Bartram. (1988 reprint) Penguin Books, New York, New York.

Brand, S. B. 1987. Small mammal communities and vegetative structure along a moisture gradient. MS Thesis, University of Florida, Gainesville.

Briggs, J. M., and K. G. Smith. 1989. Influence of habitat on acorn selection by *Peromyscus leucopus*. Journal of Mammalogy 70:35–43.

Conover, W. J. 1980. Practical nonparametric statistics. John Wiley and Sons, New York, New York.

Eisenberg, J. F. 1968. Behavior patterns. Pages 451–495 *in* Biology of *Peromyscus* (Rodentia) (J. A. King, editor.) Special Publication 2, American Society of Mammalogists.

Eisenberg, J. F. 1988. Mammalian species of the Ordway Preserve. A reference for students. Ordway Preserve Research Series, Florida Museum of Natural History Report No. 1, Gainesville.

Frank, P. A., and J. N. Layne. 1992. Nests and daytime refugia of cotton mice (*Peromyscus gossypinus*) and golden mice (*Ochrotomys nuttalli*) in south-central Florida. The American Midland Naturalist 127:21–30.

Franz, R. 1986. *Gopherus polyphemus* (gopher tortoise) burrow commensals. Herpetological Review 17:64.

Franz, R. 1990. Annotated list of the vertebrates of the Katharine Ordway Preserve-Swisher Memorial Sanctuary, Putnam County, Florida. Ordway Preserve Research Series, Florida Museum of Natural History Report Number 2, Gainesville.

Halls, L. K., editor. 1977. Southern fruit-producing woody plants used by wildlife. United States Department of Agriculture, Forest Service General Technical Report SO–16.

Harris, L. D., and P. J. Skoog. 1980. Some wildlife habitat-forestry relations in the southeastern Coastal Plain. Annual Forestry Symposium Proceedings 29:103–119.

Hilborn, R., J. A. Redfield, and C. J. Krebs. 1976. On the reliability of enumeration for mark and recapture census of voles. Canadian Journal of Zoology 54:1019–1024.

Humphrey, S. R., J. F. Eisenberg, and R. Franz. 1985. Possibilities for restoring wildlife of a longleaf pine savanna in an abandoned citrus grove. Wildlife Society Bulletin 13:487–496.

Jones, C. A. 1989. First record of pawpaw consumption by the Florida mouse. Florida Scientist 52:7.

Jones, C. A. 1990. Microhabitat use by *Podomys floridanus* in the high pine lands of Putnam County, Florida. Ph.D. Dissertation, University of Florida, Gainesville.

Jones, C. A., and R. Franz. 1990. Use of gopher tortoise burrows by Florida mice (*Podomys floridanus*) in Putnam County, Florida. Florida Field Naturalist 18:45–51.

Jones, C. A., and J. N. Layne. In Press. *Podomys floridanus*. Mammalian Species.

Kantola, A. T., and S. R. Humphrey. 1990. Habitat use by Sherman's fox squirrel (*Sciurus niger shermani*) in Florida. Journal of Mammalogy 71:411–419.

Layne, J. N. 1970. Climbing behavior of *Peromyscus floridanus* and *Peromyscus gossypinus*. Journal of Mammalogy 51:580–591.

Layne, J. N. 1978. Florida mouse. Pages 21–22 *in* Rare and endangered biota of Florida. Volume 1: Mammals (J. N. Layne, editor). University Presses of Florida, Gainesville.

Layne, J. N. 1990. The Florida mouse. Pages 1–21 *in* Proceedings of the eighth annual meeting gopher tortoise council (C. K. Dodd, Jr., R. E. Ashton, Jr., R. Franz, and E. Wester, editors). Florida Museum of Natural History, Gainesville.

Merriam, C. H. 1890. Descriptions of twenty-six new species of North American mammals. North American Fauna 4:1–54.

Milstrey, E. G. 1987. Bionomics and ecology of *Ornithodoros* (*P.*) *turicata americanus* (Marx) (Ixodoidea: Argasidae) and other commensal invertebrates present in the burrows of the gopher tortoise, *Gopherus polyphemus* Daudin. Ph.D. Dissertation, University of Florida, Gainesville.

Norman, E. M., and D. Clayton. 1986. Reproductive biology of two Florida pawpaws: *Asimina obovata* and *A. pygmaea* (Annonaceae). Bulletin of the Torrey Botanical Club 113:16–22.

Packer, W. C., and J. N. Layne. 1991. Foraging site preferences and relative arboreality of small rodents in Florida. American Midland Naturalist 125:187–194.

Semel, B., and D. C. Andersen. 1988. Vulnerability of acorn weevils (Coleoptera: Curculionidae) and attractiveness of weevils and infested *Quercus alba* acorns to *Peromyscus leucopus* and *Blarina brevicauda*. American Midland Naturalist 119:385–393.

Umber, R. W. 1975. Impact of pine plantation succession on sandhill wildlife in central Florida. MS Thesis, University of Florida, Gainesville.

Willson, M. F., and D. W. Schemske. 1980. Pollinator limitation, fruit production, and floral display in pawpaw (*Asimina triloba*). Bulletin of the Torrey Botanical Club 107:401–408.

Young, B. L. 1983. Food supplementation of small rodents in the sand pine scrub. MS Thesis, University of Central Florida, Orlando.

Young, B. L., and J. Stout. 1986. Effects of extra food on small rodents in a south temperate zone habitat: demographic responses. Canadian Journal of Zoology 64:1211–1217.

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